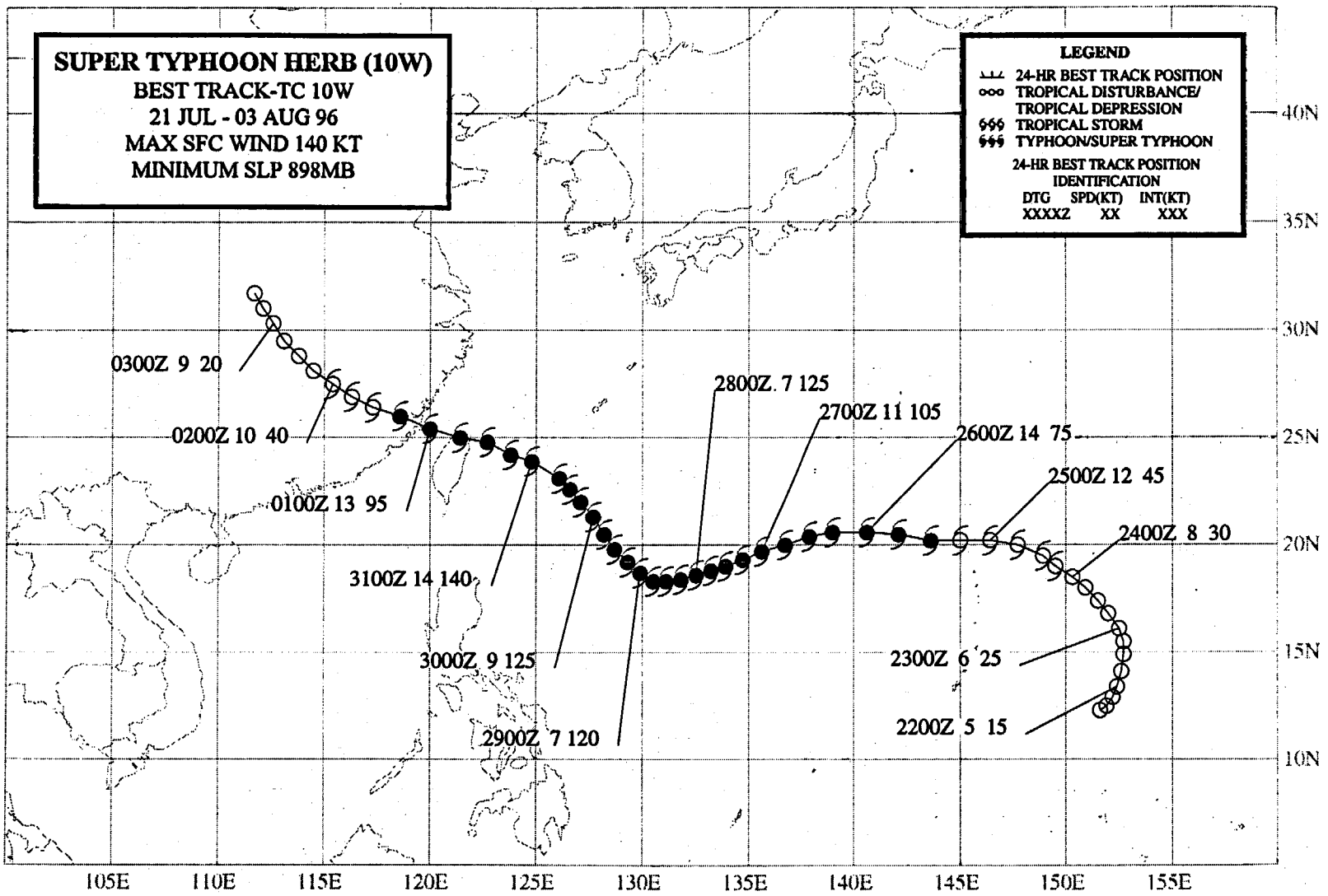
SUPER TYPHOON HERB (10W)
BEST TRACK-TC 10W
21 JUL - 03 AUG 96
MAX SFC WIND 140 KT
MINIMUM SLP 898MB
LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/ TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XXX
0300Z 9 20
0200Z 10 40
0100Z 13 95
3100Z 14 140
3000Z 9 125
2900Z 7 120
2800Z. 7 125
2700Z 11 105
2600Z 14 75
2500Z 12 45
2400Z 8 30
2300Z 6 25
2200Z 5 15
40N
35N
30N
25N
20N
15N
10N
105E
110E
115E
120E
125E
130E
135E
140E
145E
150E
155E

SUPER TYPHOON HERB (10W)

I. HIGHLIGHTS

When Herb formed, it became the easternmost of three tropical cyclones simultaneously active along the monsoon trough — the other two were Frankie (08W) and Gloria (09W). Herb's mode of formation was somewhat unusual: the cloud cluster from which it developed became organized into a "fishhook" cloud pattern. While moving generally westward toward China, Herb peaked twice in intensity. As the tropical cyclone neared its second peak intensity, it possessed a large eye. In addition, Herb was also a very large tropical cyclone; the largest tropical cyclone in terms of the mean Radius of Outermost Closed Isobar (ROCI) in the WNP during 1996. Herb made landfall in the southern Ryukyu Islands, Taiwan, and mainland China. Significant property damage and loss of life were attributed to Herb in these areas. On Taiwan, a new NEXRAD WSR 88D took a direct hit from Herb, and was severely damaged.

II. TRACK AND INTENSITY

During the latter half of July, extensive amounts of deep convection formed in an east-west band extending across the WNP from the coast of Southeast Asia to the Marshall Islands. By 21 July, this cloud band had consolidated into three distinct cloud clusters (Figure 3-10-1), all of which became named tropical cyclones — from west to east: Frankie (08W), Gloria (09W), and Herb.

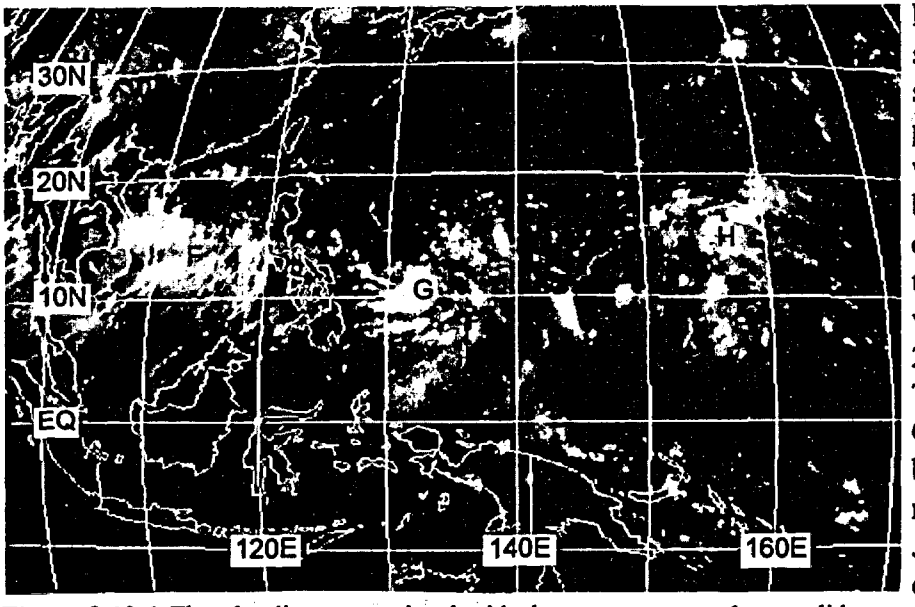

Figure 3-10-1 The cloudiness associated with the monsoon trough consolidates into three distinct cloud clusters that will soon become Frankie (08W), Gloria (09W), and Herb (201831Z July Infrared GMS imagery).

Based upon 24-hours of persistent deep convection, and synoptic data indicating the presence of an associated weak low-level cyclone beneath upper-level anticyclonic flow, the tropical disturbance that became Herb was first mentioned on the 210600Z July Significant Tropical Weather Advisory. Convection in this disturbance remained poorly organized until the morning of 23 July, when deep convection consolidated within a smaller area, and microwave imager data and visible satellite imagery indicated improved organization of the low-level circulation center (LLCC). This prompted the JTWC to issue a TCFA valid at 230000Z. Continued improvements in the organization of low-level cloud lines accompanying a persistent area of deep convection near the LLCC led to the first warning on Tropical Depression (TD) 10W valid at 230600Z.

Based upon satellite intensity estimates, TD 10W was upgraded to Tropical Storm Herb on the warning valid at 240600Z. After becoming a tropical storm, Herb's central deep convection began to detach from the peripheral monsoon cloudiness to form a fishhook pattern (Figure 3-10-2).

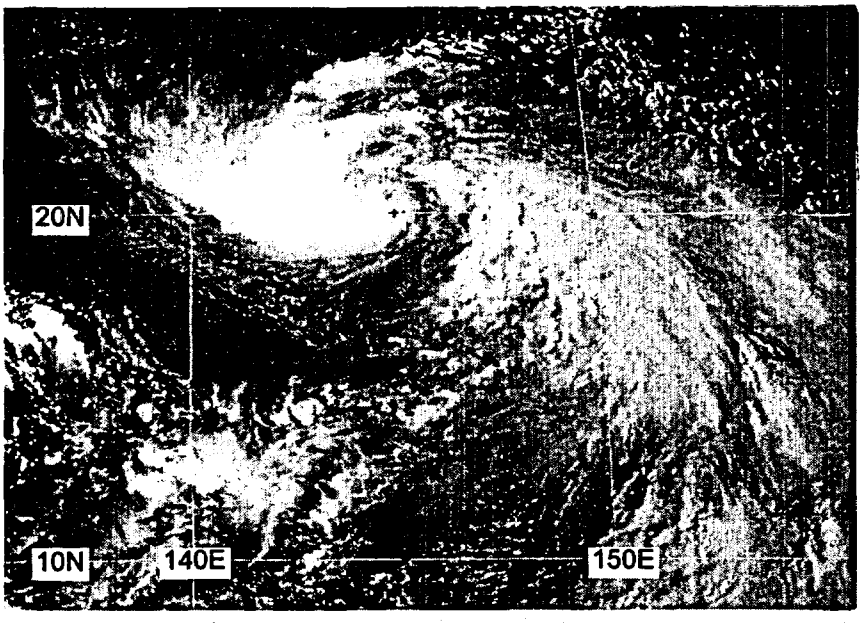

Figure 3-10-2 Herb's central deep convection begins to detach from the end of a fishhook shaped cloud pattern (250631Z July visible GMS imagery).

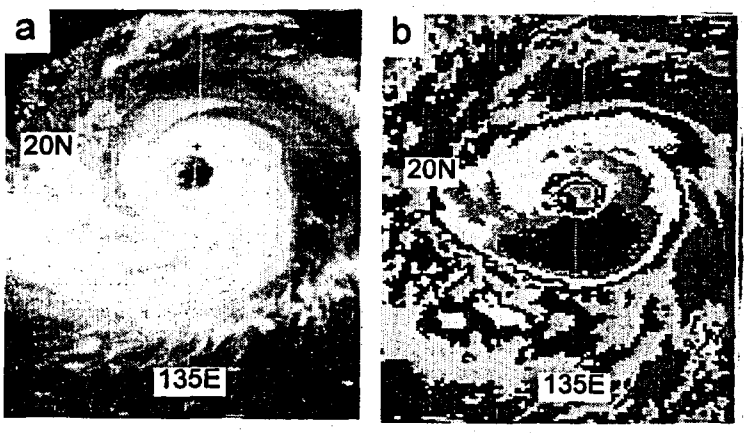

Figure 3-10-3 Herb nears its first of two intensity maxima: (a) 270331Z July visible GMS imagery and (b) 270331Z July enhanced infrared GMS imagery.

As the cloud system center moved to the head of the fishhook cloud pattern, Herb's motion became more westward. On a westward heading, Herb began to intensify and grow in size. Herb became a typhoon at 251200Z, and 48 hours later it reached 125 kt (64 m/sec) (Figure 3-10-3a,b); the first of two intensity maxima. At this time, Herb was moving in an unusual west-southwestward direction. This unusual motion may have been the result of an indirect interaction with Typhoon Gloria (09W) (the various types of direct and indirect interactions between two tropical cyclones are discussed in detail by Carr and Elsberry (1994)).

On 29 July, Herb began to weaken with its intensity falling to 115 kt (59 m/sec) at 290600Z. While the typhoon weakened, the system made a gradual track change from a west-southwestward heading during 28 July to a northwestward heading during 29 July. Although weakened slightly, Herb had become a very large tropical cyclone with a mean ROCI of approximately 8.5° of great-circle arc (Figure 3-10-4). Early on 30 July, Herb began to intensify once again, reaching a peak of 140 kt (72 m/sec) at 301800Z (Figure 3-10-5). After reaching its peak intensity, Herb took a more westward course which brought it ashore on the northeast tip of Taiwan at approximately 311600Z with a landfall intensity of 130 kt (67 m/sec). Passing over Taiwan, Herb lost its eye, but then regained a ragged eye during its short passage across the Taiwan Strait. It quickly lost its eye over land in China. The final warning was issued valid at 011200Z August as the system moved farther inland and dissipated.

III. DISCUSSION

a. *Unusual genesis*

While Herb was forming in the monsoon trough, it followed an unusual developmental pathway: the deep convection associated with Herb's LLCC moved on a backwards "C" shaped trajecto-

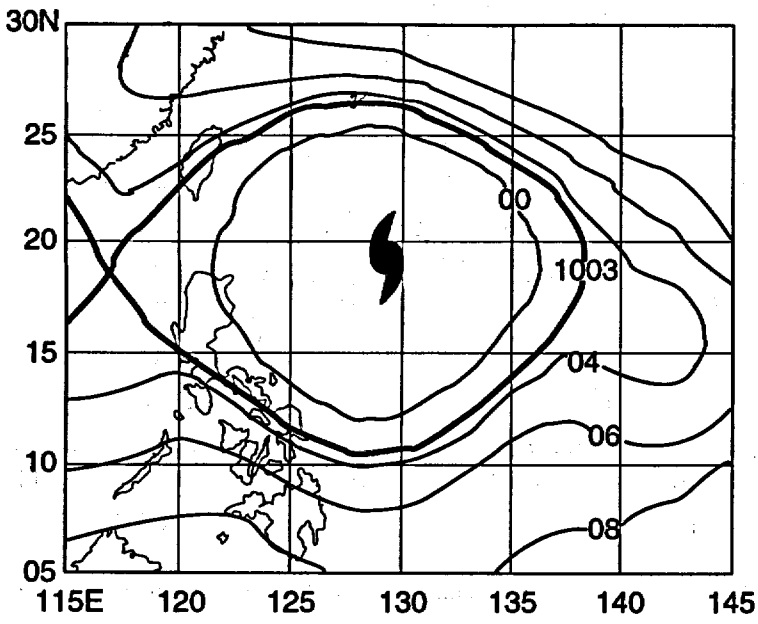

Figure 3-10-4 Herb became a very large tropical cyclone, the largest of 1996 in the WNP. As a measure of its size, the average radius of the outermost closed isobar is over 8.5° of great circle arc at 290000Z July. (290000Z July NOGAPS SLP analysis).

ry and gradually detached from the peripheral monsoon cloudiness to form a fishhook pattern (Figure 3-10-2). When the monsoon trough becomes organized as a monsoon gyre (Lander 1994) (see Appendix A), the large-scale monsoon cloud band often becomes organized into a large fishhook cloud pattern. One, or more, tropical cyclones may traverse the eastern periphery of the monsoon gyre (in a cyclonic orbit of the gyre) and emerge from the end of the fishhook. Although smaller in scale than the monsoon gyres cited by Lander (1994), the process of organization of the monsoon cloud pattern into a fishhook, and the backwards "C" motion of Herb as the fishhook evolved, are consistent with the cloud evolution and behavior of tropical cyclones associated with larger monsoon gyres.

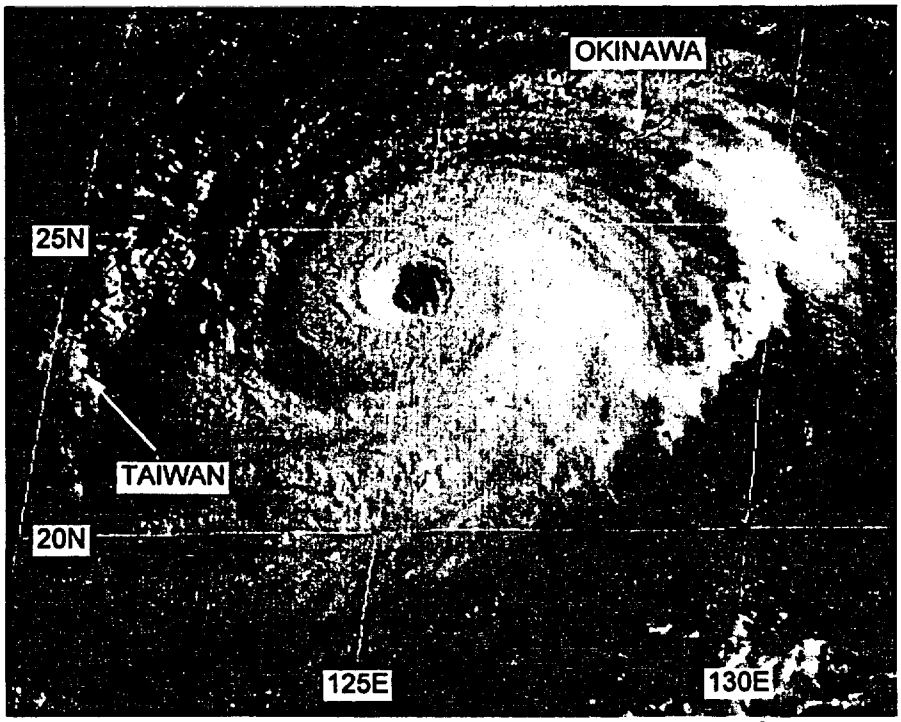

Figure 3-10-5 Herb at peak intensity of 140 kt (72 m/sec) (302224Z July visible GMS imagery).

b. *Three periods of intensification*

The time series of the DD numbers obtained for Herb (Figure 3-10-6) indicate three maxima: one maximum at approximately 270000Z, a second at approximately 281800Z, and a third sustained maximum during 30 July. The first maximum indicated by the DD algorithm occurred a little bit ahead of the first maximum in the final best track intensity. The best track intensity does not reflect the fall and rise of the DD time series to its second maximum. One reason for this, is that as the T-number falls, the Dvorak

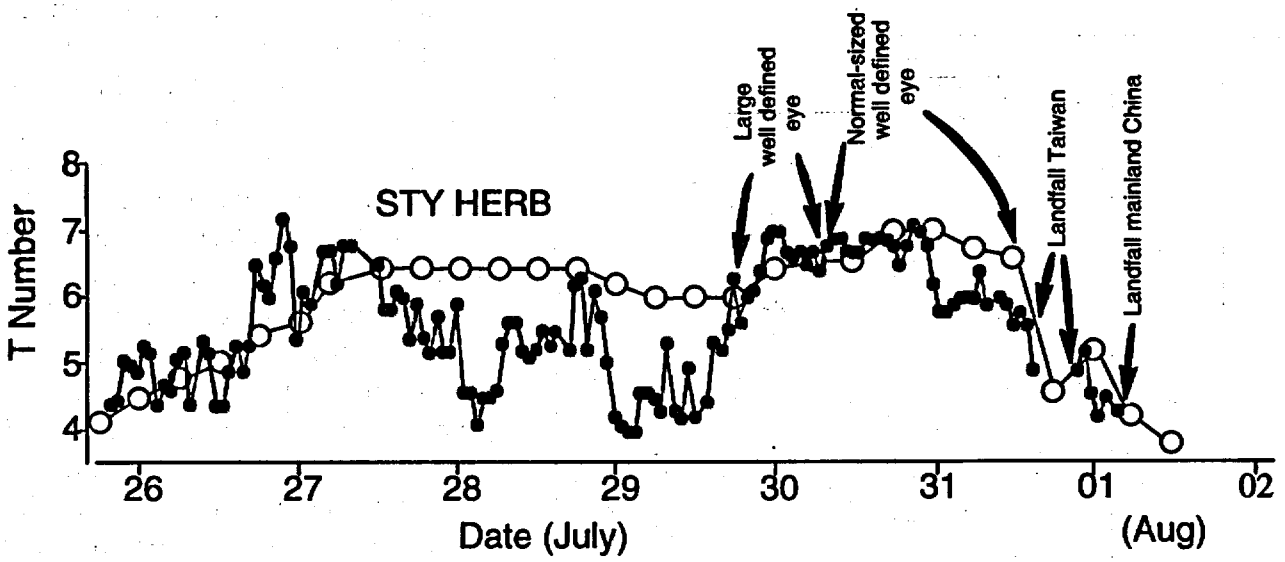

Figure 3-10-6 The time series of Herb's Digital Dvorak "DD" numbers (small dark circles) with the final best track intensity superimposed (large open circles).

technique requires that the current intensity be held one-half to one number higher than the T-number for at least 12 hours. For the most part, this is true of a comparison of Herb's DD time series with its final best track intensities (Figure 3-10-6). The second drop of intensity indicated on the DD time series was reflected by a slight drop in the warning and best track intensity before both rose once again to the peak that occurred on 30 July. Note that the DD time series contains some rather large fluctuations that do not appear in the final best track intensity time series. It is not known to what extent the fluctuations in the DD time series may represent actual short term changes in the intensity of tropical cyclones (see Bart's (04W) summary for a discussion of the DD algorithm).

c. *Largest tropical cyclone of 1996*

Super Typhoon Herb was the largest tropical cyclone of 1996. Using the mean ROCI as a measure of Herb's size, the system surpassed the threshold of the "very large" size category used by the JTWC (see Appendix A). At its largest, the mean ROCI of Herb was about 8.5° of great-circle arc (GCA) (Figure 3-10-4).

Tropical cyclone size is a very difficult parameter to objectively measure. Merrill (1984) classified a tropical cyclone as "small" if the mean ROCI was three degrees (180 nm, 335 km) GCA, or smaller; as "medium" if the mean ROCI was between three to five degrees GCA (180 nm (335 km) to 300 nm (555 km)), and as "large" if the mean ROCI was greater than five degrees GCA (greater than 300 nm). The Japan Meteorological Agency (JMA) recognizes two additional size categories — "very small" and "ultra large" — that mesh neatly with Merrill's scheme. The definitions of size used herein (see Appendix A) have been adapted by a mesh of the JMA size categories with those of Merrill.

d. *Eyewall mesocyclonic vortices as seen by Taiwan's NEXRAD*

Eyewall mesocyclonic vortices (EMs) were first detected and documented in airborne Doppler radar data by Marks and Houze (1984) and also with aircraft inertial navigation equipment as noted by Black and Marks (1991). Stewart and Lyons (1996) identified EMs with the Guam

NEXRAD in association with the passage of Super Typhoon Ed (1993). Until the implementation of the NEXRAD radar network in the United States during the early 1990s, only chance encounters with EMs have occurred during reconnaissance aircraft penetrations. However, now that Doppler velocity data are available, strong mesocyclones associated with TC outer convective bands and eyewall convection are frequently detected.

Stewart et al. (1997) used NEXRAD data to show that EMs in the wall clouds of TC eyes may be a mechanism for TC intensification and for extreme wind bursts in TCs as noted with Hurricane Andrew damage (Wakimoto and Black 1993). In three cases (including Herb), the TC underwent a period of rapid intensification during which time several vertically deep, EMs formed prior to the occurrence of rapid intensification and persisted for several hours while rapid deepening was occurring. Comments from Stewart et al. (1996) include:

"Approximately three hours prior to landfall in Taiwan, satellite imagery indicated Herb had weakened . . . In contrast, the [Taiwan NEXRAD] indicated that Herb was actually intensifying . . . As early as 310656Z July, [the NEXRAD] indicated intense EMs had begun to develop and this trend continued until the last available data at 311350Z [when the data record ended because of damage to the radar by high wind.] . . . . Although the [Taiwan NEXRAD] detected several EMs (as many as 6 EMs occurred simultaneously in the eyewall), one particular EM became quite intense and persisted for more than 1.5 hours just prior to Herb's landfall . . . This particular EM peaked at 311314Z with a rotational shear of 0.075/sec which is more than triple the [NEXRAD] criteria for a Tornadic Vortex Signature . . ."

Based on observations of EMs in TCs (including Herb), Stewart et al. (1997) conclude that the EMs appear to have a positive feedback on TC intensification.

IV. IMPACT

In addition to the destruction of Taiwan's NEXRAD, Herb caused extensive damage to property and agriculture in Taiwan and China. At least 51 lives were lost and 22 missing in Taiwan. Twenty-four of these lives were lost in the city of Nantou, 120 miles south of Taipei, due to rockslides and flooding. Daily rain totals of nearly 40 inches (1000 mm) were reported over the central mountain range. An estimated US $5 billion dollars of damage to crops, roads and power equipment was reported in Taiwan. In China, rains from Herb contributed to flooding that killed upwards of 250 people. In Fujian Province, 950 miles south of Beijing, at least 233 people were reported killed and 284 missing when flooding destroyed 70,000 homes.